State of California
California Regional Water Quality Control Board, Los Angeles Region

Draft Technical Staff Report

Evidence in support of an Amendment to the *Water Quality Control Plan for the Coastal Watersheds of Los Angeles and Ventura Counties*

to Prohibit On-site Wastewater Disposal Systems in the Malibu Civic Center Area

Technical Memorandum #3: *Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation*

By
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** The author would like to thank Regional Board staff, Joe Luera and interns Albert Chu, Shentong Lu, Shannon Liou, Justin Tang, Tessa Nielsen, Ben Leu, Holly MacGillivray, Thomas Palmieri, Ryan Thatcher and Yifei Tong for their assistance in preparing map, tables and graphs.*

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Technical Memorandum #3: ***Pathogens in Wastewaters that are in Hydraulic Connection with Beaches Represent a Source of Impairment for Water Contact Recreation***[1]

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1. Purpose

The purpose of the memorandum is (a) to document the discharge of enterococcus, total coliform and fecal coliform, bacteria used to indicate risk of recreational waterborne illness, from on-site wastewater disposal systems (OWDS) in the Malibu Civic Center onto adjacent surface waters and beaches, and (b) to determine human health impacts on beach users from exposure to pathogens given observed levels of enterococcus in beach water.

2. Study Design and Data

The study sought to examine the distribution of bacteria in groundwater beneath the Malibu Civic Center area and surface water around Malibu Civic Center area. Fecal-indicator-bacteria are quantified in OWDS discharge, in leachfields/seepage pits, in groundwater, and in streams and beaches. OWDS performance data from permitted commercial facilities, groundwater monitoring data and beach monitoring data at the Malibu Civic Center are studied for the presence of enterococcus bacteria, which can originate in the human gut, have been used as indicators of pathogens, and are the basis of marine recreational criteria for the protection of human health.

Of the twenty permitted commercial facilities in the Malibu Civic Center under the Regional Water Quality Control Board's (Regional Board) oversight, four provided end-of-pipe measures and ten submitted groundwater monitoring results. End-of-pipe discharge reports from permitted systems document effluent quality as it enters the leachfield/seepage pit. Enterococcus densities were also examined in groundwater monitoring wells surrounding the leachfields.

The City of Malibu measures groundwater quality periodically throughout the Malibu Valley Basin which receives the effluent from the OWDS in the Malibu Civic Center area The groundwater monitoring of 20 such wells in the Malibu Civic Center area completed by the City of Malibu in 2004 and summarized by Stone Environmental, Inc. (Stone, 2004) are used for this study.

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[1] The area subject to the proposed prohibition is referred to as the Malibu Civic Center area (Figure 1). The area was defined using topographic features and drainage patterns, and encompasses the hydrologic areas of Malibu Valley (also referred to as the lower Malibu Creek watershed), Winter Canyon, and adjacent coastal strips including Amarillo Beach, Malibu Beach, Malibu Lagoon, and Malibu Lagoon Beach (aka Surfrider Beach, including First, Second, and Third Points at Surfrider). For more discussion on the prohibition boundaries defining the Malibu Civic Center area, refer to the Technical Staff Report Overview and the Environmental Staff Report.

Beach data collected as part of the Coordinated Shoreline Monitoring Plan for Santa Monica Bay beaches were used for this study. The "Santa Monica Bay Beaches Bacteria Total Maximum Daily Load Coordinated Shoreline Monitoring Plan, April 7, 2004" (CSMP) went into effect on April 28, 2004. The sites cover 44 beaches that were identified as impaired due to high fecal-indicator-bacteria and/or beach closures and therefore placed on the California Clean Water Act 2002 section 303(d) list. Detailed descriptions of standardized sampling and testing procedures can be found at http://ladpw.org/wmd/npdes/beachplan.cfm. Attachment 3-A contains a complete list of the beaches in the CSMP.

The study sought to determine if enterococcus bacteria were present continuously along likely hydrological transport paths, such as those documented for the Civic Center area or at other beaches described in the literature, from the OWDSs in the Civic Center area to the adjacent beaches. Beach enterococcus densities, and their frequency distributions, were compared to variables such as watershed size, urban acreage, beach visitor population, wave strength, setting such as lagoon or estuary, number of roofs seen on air photo (where indicative of a septic system), preceding winter weather as rainfall, and annual variation, to identify correlations with the highest Pearson's Correlation coefficients. Although the study design does not eliminate all possible alternative bacteria sources, it focused on bacteria delivered to the beach via groundwater by examining the beaches during the summer months (May to the end of October) when other bacteria sources, such stormwater and overland urban runoff, are known to be at a minimum. Further, examining bacteria during storm-free dry conditions minimizes other transport mechanisms, such as rainfall or heavy wave action, which could move bacteria onto the beach face.

Compilations of the data reviewed have been provided for public review. Over 8000 records collected for CSMP were compiled and released with a summary of the beach characteristics on August 24, 2009 on the Regional Water Quality Control Board Website www.waterboards.swrcb/los angeles. Among these records, the Civic Center beaches sampled by CSMP are Malibu Colony Beach labeled as MC-1, Malibu Surfrider Beach labeled as MC-2, and the beach near Malibu Pier Beach labeled as MC-3. Sweetwater Canyon at Carbon Beach, labeled as SMB 1-13, is the Civic Center beach which lies furthest to the southeast. Marie Canyon, labeled as SMB 1-12, is the beach which lies furthest to the northwest and just outside the Malibu Civic Center Prohibition area. Attachment 3-B contains an expanded reference list including those documents cited here. Attachment 3-C contains a list of selected correlation coefficients between the Civic Center Beaches.

Early Technical Review

An Early Technical Review (ETR) of this work was conducted between June 8, 2009, and the public release of this document. The ETR resulted in recommendations from the reviewers (a) to enhance the confidence of the conclusions using statistics, (b) to recommend additional studies to confirm and extend the results shown here, (c) to emphasize the complexity of the subsurface hydraulic and microbiological environment between OWDS discharge and the ocean, and (d) to verify the relationship between human illness from marine recreational activities and coastal OWDS use. In response to these comments, additional statistical results were generated and human health risks estimates were based on a site-specific study. The Early Technical Reviewers were Dr. Mark Gold (Heal the Bay), Mr. Steve Weisberg and Dr. John Griffith (Southern California Coastal Water Research Project or SCCWRP), Dr. Alexandria Boehm

(Stanford University) and Dr. John Izbicki (US Geological Survey), all of whom have completed research on microbial water quality at beaches.

Peer Review

Independent Peer Review was also conducted through a contract with the University of California at Berkeley and the State Water Resources Control Board, with the comments and response to comments released to the public and considered with this document by the Regional Board.

Integration with Ongoing Studies

An epidemiology study of Surfrider Beach by SCCWRP is ongoing with fieldwork conducted during the summer of 2009. Groundwater assessment was conducted during a ten-day period in July 2009 by Dr. John Izbicki of the USGS. The City of Malibu reports that Richard Ambrose and Jenny Jay of UCLA conducted a study of *Bacteroides* in Malibu Lagoon in 2009. General descriptions of the ongoing studies are available from the Regional Board.

3. Results

Hydrological Connection

The existence of a hydrological connection between the beaches and the groundwater underlying the Malibu Civic Center area has been well established in existing literature, by groundwater models (Stone, 2005; Questa, 2003), by surface water models (Malibu Creek and Lagoon nutrient TMDL 2003; Malibu Creek and Lagoon bacteria TMDL, 2004), and as described in the 2004 Memorandum of Understanding between the City of Malibu and the Regional Board. The City of Malibu's ongoing hydrology study, as expressed in the planning documents provided to Board staff in September, 2008, seeks to quantify and model the groundwaters of the Civic Center and their hydrological connection with the ocean.

Enterococcus is found all along hydrological transport paths from the Onsite Wastewater Disposal Systems in the Civic Center Area to the beaches.

Bacteria in Groundwater

End-of-pipe bacteria measurements are reported for four permitted commercial sites in the Malibu Civic Center. Disinfection has failed in each example except Malibu Beach Inn. The enterococcus values are considered to be typical for non-disinfection systems like most residential OWDSs. A more complete description of the extent of enterococcus in the groundwater basin is included as part of Technical Memo #2.

Table 1: End-of-Pipe Effluent Bacteria Densities (MPN/100mL) reported for permitted Malibu Civic Center Commercial Facilities where Disinfection has failed.

Site	Total	Fecal	Enterococcus
Malibu Creek Preservation	1,600	350	46
	1,600	140	110
Malibu Beach Inn[2]	Not measured	2	2
	Not measured	2	2
Malibu Colony Plaza	105	2	2
	4,000	2	2
	1,600	1,600	2,419
	1,600	1,600	2,419
Fire Station 88	1,600	1,600	2,419
	9,000	Not available	90,000
	24,000	24,000	24,000
	30,000	2,400	50,000
	240,000	Not available	240,000
	300,000	50,000	1,600,000

Shaded measures on the chart show where fecal-indicator-bacteria values are above the water quality objectives for protection of body contact recreation (REC-1)). The end-of-pipe data were provided to document that enterococcus is discharged from OWDSs into groundwater. Staff notes the values are higher than 'average' enterococcus ranges reported in raw sewage or natural waters. Enterococcus values in wells and at end-of-pipe have been reported ranging to 1 X 10^8, suggesting that high values are not computational, sampling or reporting errors.

Elevated bacteria levels were found throughout the Malibu Valley groundwater basin, which underlies the Malibu Civic Center area, and are also reported in 2004 by Stone Environmental's "Final Report-Risk Assessment of Decentralized Wastewater Disposal Systems in High Priority Areas in the City of Malibu, CA". Figure 1 shows the locations of monitoring wells in Stone's study. Elevated subsurface enterococcus densities are seen adjacent to the receiving waters. Fifteen out of 20 City wells, and 16 out of 27 permit monitoring wells, located at the edge of leachfields, contained a maximum enterococcus density exceeding the single sample maximum water quality objective of 104 MPN/100ml for protection of the beneficial use of REC-1, i.e., 31 out of the total 47 wells (76%) have an exceedance (Figure 2 and 3). Importantly, the occurrence of enterococcus in groundwater at these wells illustrates that enterococcus is present in the groundwater at the study site.

[2] Disinfection had not failed at Malibu Beach Inn, but end-of-pipe data were submitted.

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Figure 1. The maximum enterococcus measures in wells in the Civic Center area after Stone 2004.

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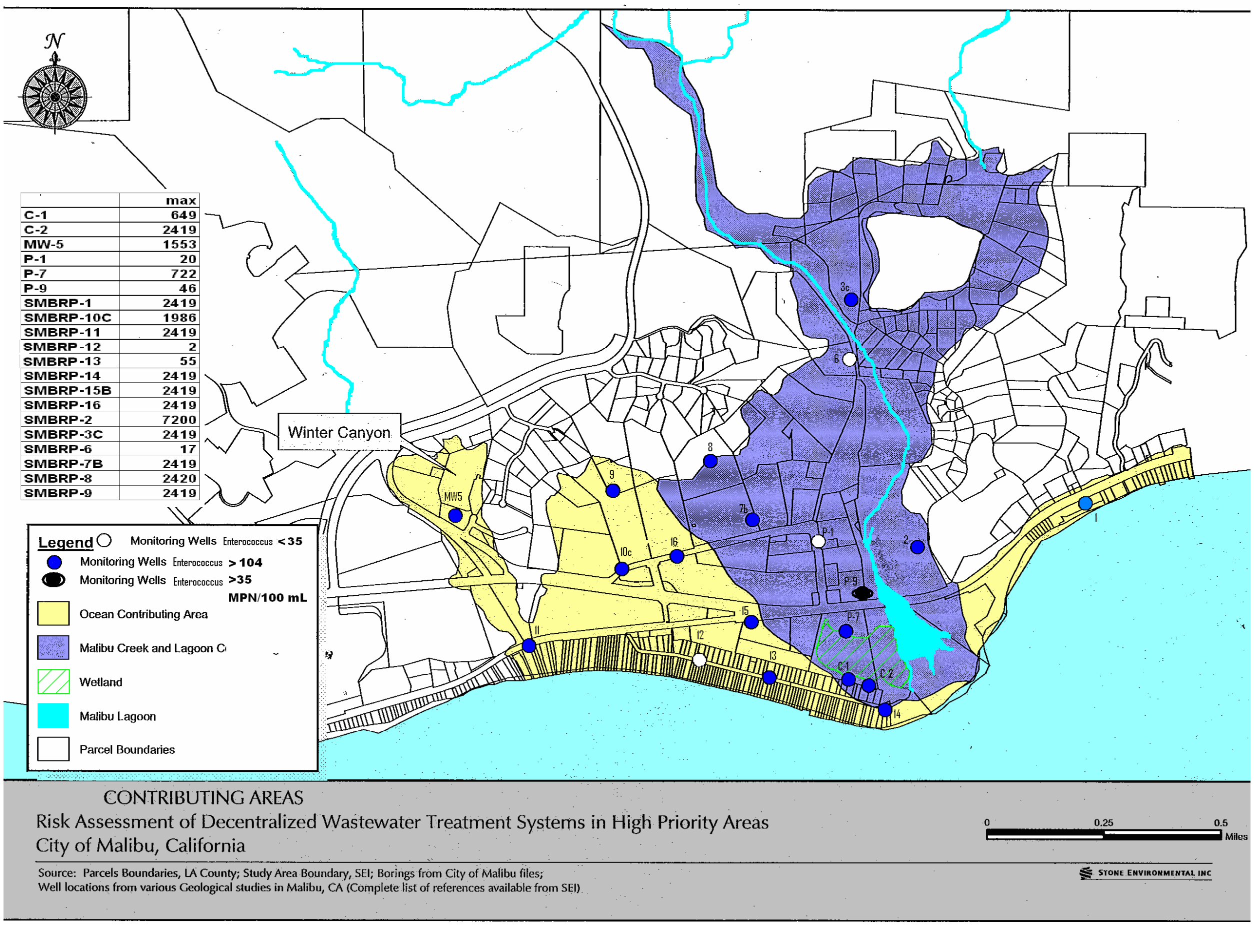


Figure 2: Chart of Maximum Enterococcus Density (MPN/100 mL) for 20 groundwater wells in the Civic Center area from Stone 2004 Study (well locations are shown in Figure 1).

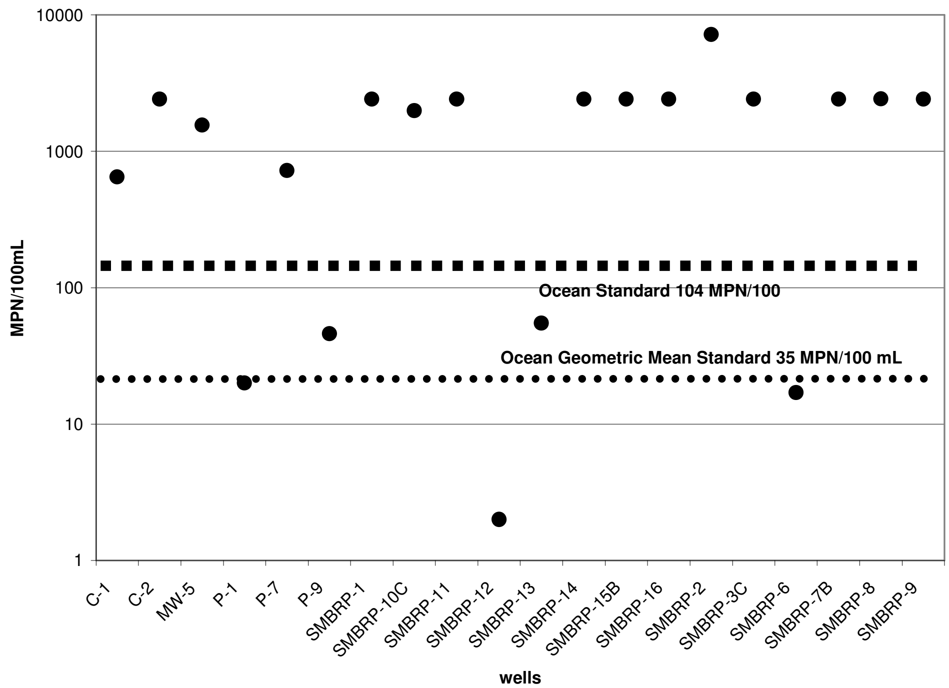
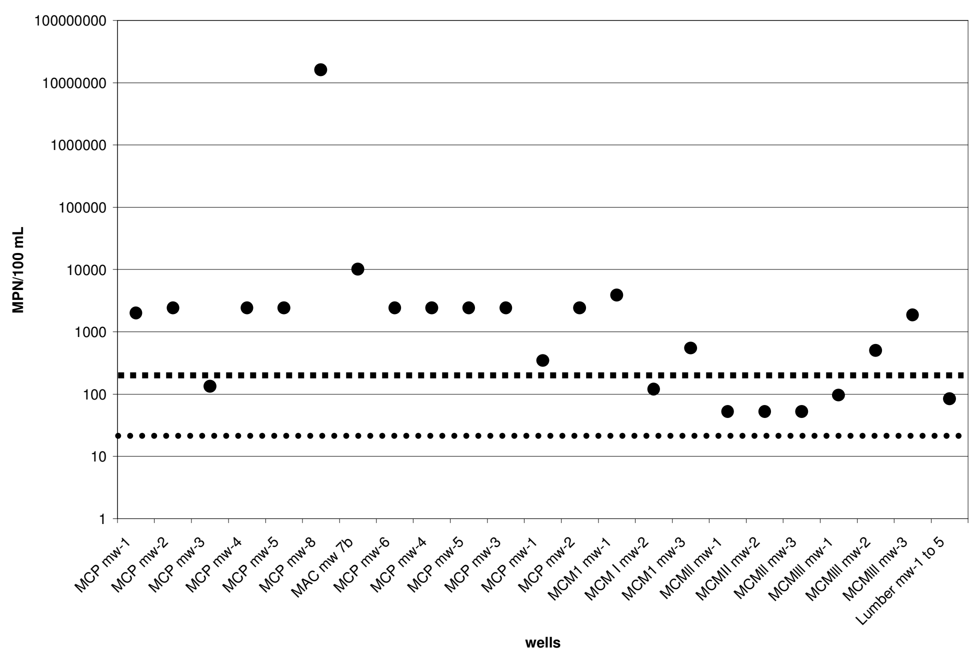


Figure 3: Chart of Maximum Enterococcus Density (MPN/100 mL) for 27 permit monitoring wells in the Civic Center area (well locations are shown in Technical Memorandum #2).



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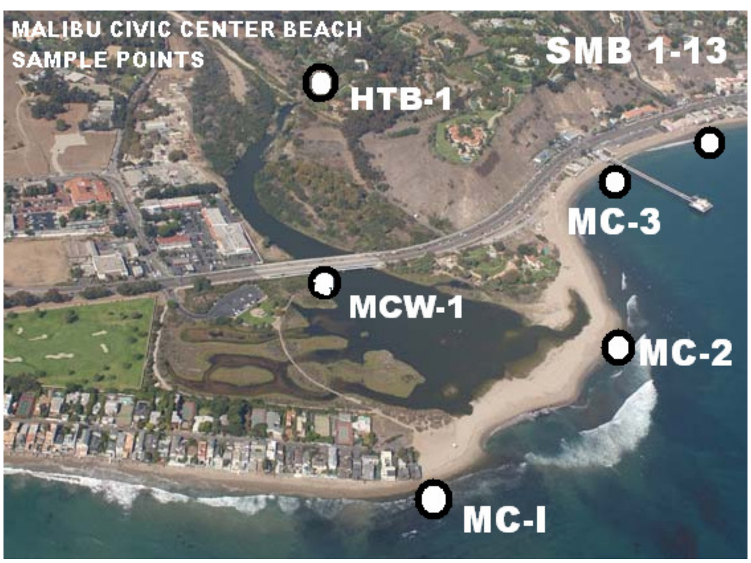
Bacteria in Surface Water: Malibu Creek and Lagoon

Several public and not-for-profit agencies measure water quality on Malibu beaches, in Malibu Creek, in the lagoon and in the ocean. This data were not collected simultaneously, may not be sampled, transported or tested with consistent protocols, and is often not compiled. Recent data from 2 of many sample sites show that last summer's levels of enterococcus are lower in the water entering Malibu Lagoon from the Malibu Creek watershed (see HTB-1 in Figure 4), than downstream of the Malibu Civic Center area (MCW-1). The contrast can be seen at Lower Malibu Creek sampling station HTB-1 and Lagoon sampling station MCW-1.

Researchers have recently released data, but not interpretations, of water quality in the lagoon and creek that may ultimately lead to a better understanding of the temporal relationship between bacteria sources and transport mechanisms such as tides, creek flow volumes, groundwater discharge volumes, and rainfall. The recent data provided in Figure 5 demonstrate that periods have been observed when Malibu Creek is not the only source of bacteria in the lagoon. Given the elevated concentrations of enterococcus observed in the groundwater beneath the civic center, and Stone's (2004) conclusion that about half of groundwater is supplied by OWDSs and most of the groundwater makes it way to the ocean, the existence of Malibu Civic Center groundwater discharge is considered a possible source of increased levels of enterococcus in the Lagoon. Typically during the summer, bacteria from any source must travel via groundwater beneath the Surfrider Beach berm before discharging into the wave zone at MC-2, as seen in Figure 4, because the beach is not broken by overland flow.

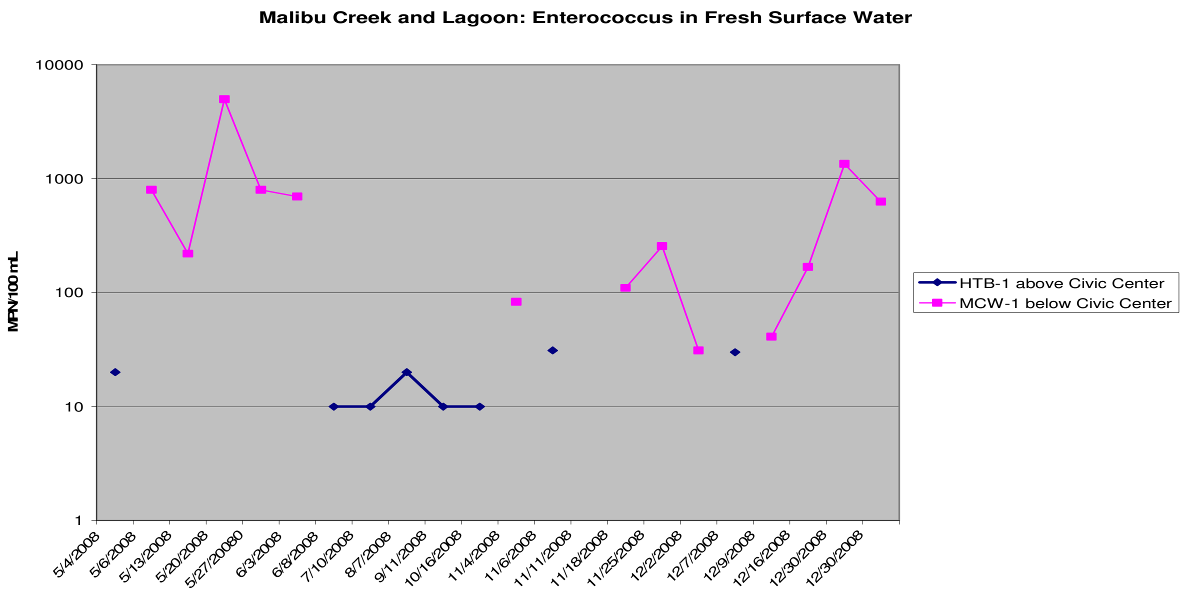
Figure 4: Malibu Civic Center Surface Water and Beach Sampling Points.



Sampling Point HTB-1 can be seen in Figure 4 where surface water from Malibu Creek watershed enters the Lagoon, MCW-1 where Malibu Creek enters Malibu Lagoon after receiving groundwater discharge from the Malibu Civic Center. The groundwater contains enterococcus which increases in concentration in the Lagoon, as shown in Figure 5. Also seen are beach sampling points MC-1 at the beach adjacent to

Malibu Colony, MC-2 at the breach point of Malibu Lagoon on Surfrider Beach, MC-3 at the beach adjacent to Malibu Pier and SMB-1-13 at Carbon Canyon Beach where Sweetwater Canyon discharges.

Figure 5: Summer 2008 Enterococcus above and below Malibu Civic Center in the Lagoon[3]



Bacteria in Surface Water: Beaches

The frequencies with which bacteria at Surfrider Beach, Malibu Colony Beach, adjacent to Malibu Pier and Sweetwater Canyon, and Marie Canyon Beach exceed the water quality objectives for enterococcus in the summers of 2005, 2006 and 2008 are listed here. A figure comparing these violations of the water quality standards for the protection of contact recreation beneficial use (REC-1) are displayed in Figure 6.

[3] Data have been collected at these locations for additional dates, but these data are the most recent and documents simultaneous measurements at upstream and downstream locations in the lagoon.

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Table 2: Exceedences of single sample Enterococcus water quality standard[4].

Days/Frequencies with Enterococcus >104 MPN/100mL	2005	2006	2007	2008
Adjacent to Malibu Pier (MC 3)	0 (0)	2 (6.7%)	2 (7.1%)	0 (0)
Surfrider Beach (MC-2)	10 (14.3%)	25 (19.2%)	4 (3.1%)	12 (9.2%)
Malibu Colony (MC-1)	1 (6.7%)	5 (15.6%)	0 (0)	0 (0)
SMB 1-13 Sweetwater Canyon at Carbon Beach (southeast)	5 (27.8%)	12 (31.6%)	1 (3.7%)	0 (0)
SMB 1-12 Marie Canyon(northwest)	16 (72.7%)	55 (82.1%)	16 (38.1%)	13 (33.3%)

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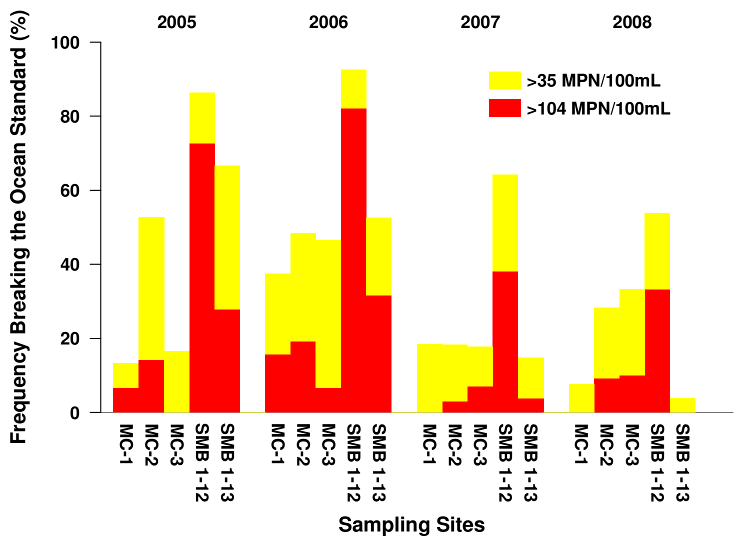
[4] The data summarized here were collected at each site four times a month from April through October

Figure 6: Cumulative frequencies of enterococcus concentrations that failed to meet the ocean discharge standards in Malibu Civic Center beaches



On the beaches, bacteria are typically present at levels above water quality objectives at Malibu Colony (MC-1), Surfrider Beach (MC-2), and adjacent to Malibu Pier (MC-3). The pollution on beaches has been quantified in the 2002 303(d) list, Heal the Bay's beach report cards, and the Regional Board's Santa Monica Bay Beaches Bacteria TMDLs. Further, the Regional Board issued a Notice of Violation (NOV) for bacteria adjacent to the Malibu Civic Center beaches in March 2008. It identified violations of the waste discharge requirements established in Board Order No. 01-182, as amended by Order No. R4-2006-0074 and Order No. R4-2007-0042, pertaining to the Los Angeles MS-4 Permit controlling urban runoff and stormwater discharges. Tables 3, 4 and 5 show the water quality measures upon which the NOV was based for Malibu Civic Center Beaches.

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Table 3: Surfrider beach: Fecal-Indicator Bacteria Violations[5]

Surfrider Beach MC-2 Date of Violation(s)	Single Sample Result (MPN/100 ml)			
	Total Coliform	Fecal Coliform	Enterococcus	Total Coliform (Fecal:Total Coliform Ratio > 0.1)
Basin Plan Limit	**10,000**	**400**	**104**	**1,000**
9/14/2006		1,100		6,800
9/15/2006		1,100		7,900
9/16/2006				
9/17/2006				
9/18/2006				
9/19/2006				
9/20/2006				
9/21/2006				
9/22/2006				
9/23/2006				
9/24/2006				
9/25/2006				
9/26/2006				
9/27/2006				
9/28/2006		500		
9/29/2006		430		2,200
9/30/2006				1,400
10/1/2006				
10/2/2006				
10/3/2006	>13,000	6,300		>13,000
10/4/2006				
10/5/2006	13,000	7,300	1,400	13,000
10/6/2006				
10/7/2006		740		
10/8/2006				
10/9/2006				
10/10/2006		1,000	530	5,500
10/11/2006				
10/12/2006				
10/13/2006				
10/14/2006				
10/15/2006				
10/16/2006				

[5] Data listed here were gathered for enforcement purposes and does not represent all the information gathered in a particular year. The geometric mean calculations were incompletely documented in an 9/9/09 draft and have been deleted.

10/17/2006		1,300		6,300
10/18/2006			110	1,100
10/19/2006				
10/20/2006		500		
10/21/2006				
10/22/2006				
10/23/2006				
10/24/2006				
10/25/2006		3,200	160	3,200
10/26/2006				
10/27/2006		430	110	3,400
10/28/2006				
10/29/2006				
10/30/2006				
10/31/2006				
4/6/2007		580		3,400
4/7/2007	>13,000	1,600		>13,000
4/24/2007	11,000	740		
4/25/2007	11,000	7,300		11,000
4/27/2007		430		1,600
5/18/2007		430	190	
5/19/2007		430		
6/2/2007			270	
6/16/2007		8,700	310	9,600
10/19/2007		500		1,300
10/20/2007	>13,000	830		
10/24/2007	11,000	500		
10/30/2007		580	120	
10/31/2007		910		5,900
Total Violations	**7**	**25**	**9**	**18**

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Table 4: Malibu Colony: Fecal-Indicator Bacteria Violations

MC-1 Malibu Colony Date of Violation(s)	Single Sample Result (MPN/100 ml)			
	Total Coliform	**Fecal Coliform**	**Enterococcus**	**Total Coliform (Fecal:Total Coliform > 0.1)**
Basin Plan Limit	**10,000**	**400**	**104**	**1,000**
9/14/2006				
9/15/2006				
9/16/2006				
9/17/2006				
9/18/2006				
9/19/2006				
9/20/2006				
9/21/2006				
9/22/2006				
9/23/2006				
9/24/2006				
9/25/2006				
9/26/2006				
6/4/2007		419		
Total Violations	**0**	**1**	**0**	**0**

Table 5: Adjacent to Malibu Pier: Fecal-Indicator Bacteria Violations

Malibu Pier MC-3 Date of Violation(s)	Single Sample Result (MPN/100 ml)			
	Total Coliform	**Fecal Coliform**	**Enterococcus**	**Total Coliform (Fecal:Total Coliform > 0.1)**
Basin Plan Limit	**10,000**	**400**	**104**	**1,000**
10/10/2006			422	
10/11/2006				
10/12/2006				
10/13/2006				
10/14/2006				
10/15/2006				
10/16/2006				
10/17/2006				
10/23/2006				
10/24/2006				
10/25/2006				

10/26/2006				
10/27/2006				
10/28/2006				
10/29/2006				
10/30/2006				
10/31/2006				
6/4/2007			131	
10/29/2007			109	2,046
Total Violations	**0**	**0**	**3**	**1**

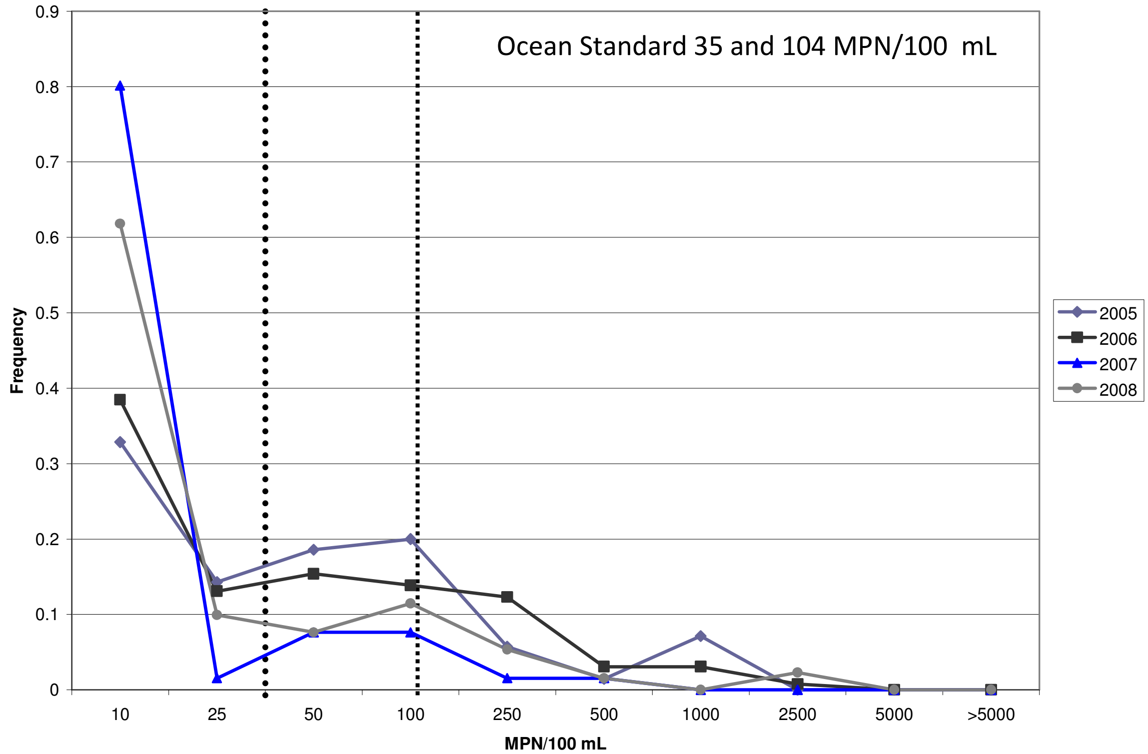
Correlations of Enterococcus with Beach Variables.

Staff did not include the results comparing beach enterococcus densities, and their frequency distributions, with other beach variables when no correlation was found. The variables examined include watershed size, urban acreage, beach visitor population, wave strength, setting such as lagoon or estuary, and number of roofs seen on air photo (where indicative of a septic system). The Pearson's Correlation Coefficient between enterococcus frequency distributions during four summers at a single beach defined statistically valid correlations (Appendix T3-C). More sophisticated statistical studies were applied, and Staff did find a statistically valid contrast between enterococcus frequency distributions from beaches adjacent to septic and sewered beaches and a statistically valid correlation between septic beaches and rainfall. These results are not included here, but included in the response to peer review.

Enterococcus on Malibu Civic Center Beaches

The enterococcus measures recorded on beaches adjacent to the Malibu Civic Center area over the summers 2005 to 2008 were sorted by interval frequency, plotted against the concentrations of enterococcus (MPN/100mL) and shown in Figures 7-9. The method was chosen to minimize the impact of varying sample sizes, to large variations in the measures and is a commonly used technique to analyze data.

Figure 7: Surfrider Beach (site MC-2) Enterococcus Interval Frequency for May-October Summer Single Measures



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The enterococcus interval frequencies calculated for the beaches for the four summers were compared using the Pearson's correlation coefficient. The number of measures were counted in each of 8 intervals: values less than or equal to ten; more than ten but less than or equal to 25; more than 25 but less than or equal to 50; more than 50 but less than or equal to 100; more than 100 but less than or equal to 250; more than 250 but less than or equal to 500; more than 500 but less than or equal to 1000; and more than 1000. The intervals approximate a logarithmic distribution, but include more intervals between 25 and 100 and between 250 and 1000, ranges in which the beaches contrasted most sharply. Pearson's correlation coefficient was applied following the method used in EPA's *Ambient Water Quality Criteria for Bacteria, 1986* as described in the following quote:

> "The examination of a number of potential indicators, including the ones most commonly used in the United States (total coliforms and fecal coliforms), was included in the study. Furthermore, the selection of the best indicator [enterococcus] was based on the strength of the relationship between the rate of gastroenteritis and the indicator density*, as measured with the Pearson's Correlation Coefficient. This coefficient varies between minus one and plus one. A value of one indicates a perfect relationship, that is, all of the paired points lie directly on the line which defines the relationship. A value of zero means that there is not linear relationship. A positive value indicates that the relationship is direct, one variable increases as the other increases. A negative value indicates the relationship is inverse, one variable decreases as the other increases.* The correlation coefficients for gastroenteritis rates are related to the various indicators of water quality from both marine and fresh bathing water as shown…. (page 5)"

Correlation coefficients between annual enterococcus frequency distributions for Surfrider Beach (MC-2) ranged from 0.78 to 0.98 suggesting little change in frequency distribution from year-to-year. Calculations of correlation coefficients for the Civic Center beaches with the best correlation, Surfrider, and the beach with the poorest correlation, next to Malibu Pier, are shown by year in Appendix T3-B:

Since enterococcus frequency distributions each year correlate well, this suggests that the distribution of bacteria frequencies is generally consistent at a beach, and not a function of random events such as swimmer shedding, the inappropriate disposal of a diaper or beach use by a homeless person.

Figure 8: Malibu Colony (site MC-1) Enterococcus Interval Frequency for May-October Summer Single Measures

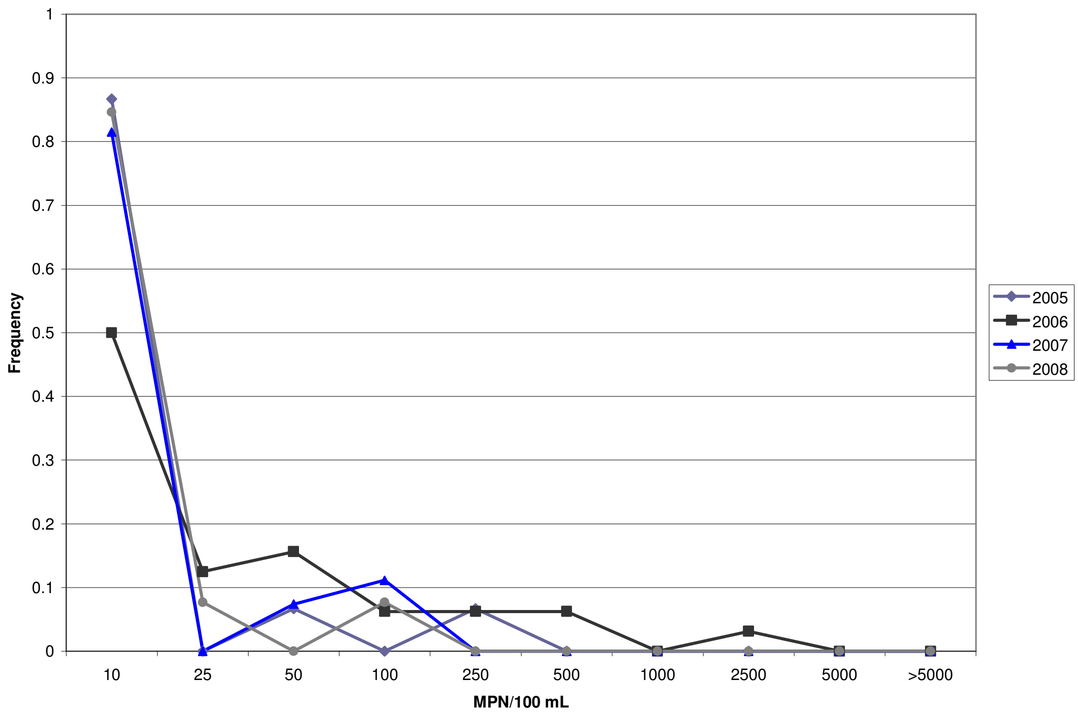

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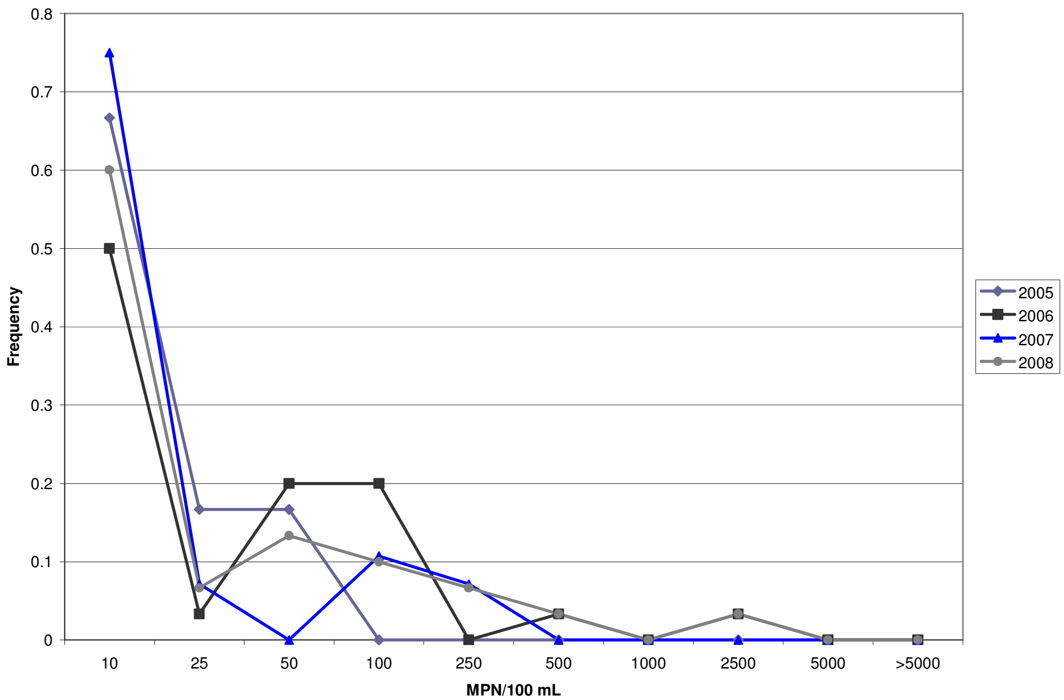
Figure 9: Adjacent to Malibu Pier (site MC-3) Enterococcus Interval Frequency for May-October Single Measures



4. Epidemiology Evidence of Human Health Impacts in the Malibu Civic Center.

Robert W. Haile and 13 co-authors (1996) completed an epidemiology study contrasting illness among immersed-head swimmers at Malibu's Surfrider Beach, Will Rogers Beach and Ashland Storm Drain. The results are summarized in Table 6. The first of its kind study on the health impacts of swimming at urban runoff contaminated ocean beaches was completed under the auspices of the USEPA's National Estuary Program's Santa Monica Bay Restoration Project (now a state commission). The study linked increased illness rates to fecal indicator bacteria densities at these beaches between June and September 1995.

Table 6: Epidemiology evidence of human impacts in Malibu

June 22 to September 17, 1995	Enterococcus Number > 104 MPN/100 mL	Percentage of days when exceeded 104 MPN/100 mL
Surfrider Beach	26	34.6
100 yards upcoast	4	5.1
100 yards downcoast	14	17.9

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Will Rogers Beach	32	45.2
100 yards upcoast	5	6.8
100 yards downcoast	7	9.6
Ashland Beach	5	6.3
100 yards upcoast	0	0
100 yards downcoast	1	1.3

Illness rates are given below for each of the days when enterococcus was above 104 MPN/100 mL at any beach. As a point of comparison, the EPA bathing water criteria for enterococcus (geometric mean of 35 MPN/100 ml and 104 MPN/ 100 ml for single samples) was determined by EPA to lead to a Highly Credible Gastrointestinal Illness (HCGI) rate of an additional 19 people with HCGI out of 1,000. The HCGI illness identified by EPA included a fever and correlates with Haile's HCGI 2 category.

Significant respiratory Disease (runny nose, coughing and fever) (SRD)	One of: vomiting, diarrhea and fever or stomach pain and fever. (HCGI 2)
45 per 1,000 swimmers	39 per 1,000 swimmers

The Santa Monica Bay bacteria and Malibu Creek and Lagoon TMDL used the term 'urban runoff' to identify surface dry weather flows not otherwise quantified and did not preclude surface flow originating as groundwater. The 1999 Haile study attributed decreasing illness in swimmers with increasing distance from the stormwater outlet point to the dilution of bacteria delivered at the stormwater outlet via 'urban runoff.' However, Haile also measured illnesses at Surfrider Beach even when no surface flow crossed the 'storm drain' sampling point. Because Stone (2004) found that under average conditions the majority of the water in the Lagoon and entering the ocean comes from groundwater, the bacteria Haile measured could be associated with groundwater flows moving through the beach face at Surfrider as well as surface flows crossing the beach.

The Malibu beaches had more exceedances of the Ocean standard than the other two study areas in 2005, 2007 and 2008, after a low-flow diversion was installed on Will Rogers Beach to limit overland flow during the summer.

<u>5. Discussion of Historic and Recent Studies</u>

Historic Studies relating Malibu Civic Center Septic Systems to Human Health Risk and Beach Pathogens

Existing technical studies (summarized in Table 7) link OWDS at the Malibu Civic Center area to beach bacteria and are discussed below:

On February 5, 1970, Los Angeles County Health provided a letter to the Regional Board stating that serious potential hazards to human health were expected to result from OWDS. LACH has repeatedly closed Surfrider Beach at the Malibu Civic Center due to high bacteria concentrations.

On July 8, 1987, Los Angles County Public Works held a public meeting to discuss a Draft Environmental Impact Report for a centralized waste water treatment plant and sewer for Malibu to address human health risk caused by OWDS system pathogens. The City of Malibu subsequently incorporated and a group of citizens brought a lawsuit to block the formation of assessment districts. The legal settlement required the new City of Malibu to provide sufficient oversight of on-site waste water treatment facilities such that they would meet Regional Board requirements.

The 1994 Ph.D. dissertation of Dr. Mark Gold "What are the health risks of swimming in the Santa Monica Bay?" identified human viruses in Malibu Lagoon and identified a potential source of the contamination as adjacent OWDS.

On January 24, 2002, the Regional Board adopted a Resolution amending the Santa Monica Beach Bacteria TMDL to the Basin Plan. The staff report found that bacteria loads from OWDS contribute to beach pathogens.

On August 30, 2004, the Stone report found that bacteria in the groundwater may enter receiving water where OWDS are found within 6-month groundwater travel time of the Ocean or Malibu Creek.

The September 17, 2004, Memorandum of Understanding between the City of Malibu and the Regional Board stated that "ordinances shall be drafted by staff, and recommended for adoption within the six-month-time-of-travel zone, as identified in the Risk Assessment Report (Stone), to provide advanced treatment and disinfection. The six-month time-of-travel zone shall include all areas contributing to Malibu Creek and Lagoon, and beaches between Sweetwater Canyon outfall and Winter Canyon outfall. OWTS located outside of the six-month-travel-time zone that cannot demonstrate compliance through inspection or that are identified as impacting groundwater by any other means shall provide adequate vertical separation and/or advanced treatment with disinfection." As of the date of this document, the City of Malibu has not provided documentation that systems within the six-month-time-of-travel zone have been upgraded to prevent bacteria discharge to the subsurface or include disinfection, nor has an ordinance to this effect been passed by the City of Malibu.

On Dec. 13, 2004, the Regional Board adopted a Resolution incorporating the Malibu Creek and Lagoon Bacteria TMDL into the Basin Plan. The staff report references a surface water model prepared by Tetra Tech which quantifies bacteria loads contributed by OWDS in the Malibu Civic Center.

Numerous studies have been completed to describe the ecosystem, hydrology, land use, possible mechanisms of waste water treatment, and costs to support policy decisions about bacteria and human health risk in the Malibu Civic Center (Ambrose et al. 2008; Bing Yen and Associates, 2001; Crawford Multari and Clark Associates, 1997, 2006, 2007; Ensitu Engineering, 2008; Gold, 1994; Jones and Stokes, 2008; Regional Board 1972, 1998, 1990, 2002, 2004b, 2008, 2008b; Lucero, 2008; Warshall, 1992; Questa, 2003; RMC, 2008; SMBRP, 1999, 2001; UCLA, 2000; URS Greiner, 1999; EPA, 2003; Stone, 2004a, 2004b, 2004c; Trim, 1994; Thorsen, 2008; and Van Beveren, 2008a, 2008b, 2008c).

Table 7: Historic Findings of Human Health Risk related to Malibu OWDS.

Date	Source	Summary
Feb 5, 1970	LA County Flood letter to Regional Board	Future OWDS will pollute groundwater in Malibu Creek with nutrients
Feb 5, 1970	LA County Health to Regional Board	Serious potential hazard to health from OWDS
Feb 11, 1970	CA DWR to Regional Board	Malibu Valley needs an area wide Water Quality plan
Apr. 8, 1970	Public Hearing SWRCB	Discontinue OWDSs, continue Regional Board surveillance
Jan. 21, 1971	CA DPH Status Ocean and streams in Malibu	Local ocean and freshwater bacteria exceed standards to protect shell fish collection in areas of development
Mar. 12, 1971	Regional Board EO to LA County Supervisors	Sewer for Malibu must be provided
May 31, 1972	Regional Board Resolution 72-4	Waste Discharge Requirements only allowed if a timetable is established to provide future connections to LA County sewer
Apr. 10, 1985	CA DPH to LA County Supervisors	Staff report and recommendation to authorize Sewer districts
July 8, 1987-Nov. 30 1988	LA Public Works Public Meeting and Malibu Citizens Committee public meetings	Draft Environmental Impact Report for Sewer, discussion of Malibu incorporating, discuss alternatives for centralized system with wetland treatment
Jan. 18, 1989	LA County Supervisors hearing	STEP WWTP system construction approved
1992	Warshall et al. report finalized	OWDS in Malibu described. Pathogen removal quantified. Author states that systems require extensive management and recommends centralized system in some areas like Civic center
1994	Mark Gold Dissertation	Three studies between 1990 and 1992 show high fecal-indicator-bacteria densities at ankle-depth wave wash and human viruses in runoff from three storm drains in Santa Monica Bay including Malibu Creek and Lagoon
May 7, 1996	Haile, et.al. 1996 epidemiology study	22,085 subjects in epidemiology study at Surfrider, Will Rogers and Santa Monica, with detailed study results for Malibu.
Dec. 14, 1998	Regional Board Resolution 98-023	Directs Report of Waste Discharge for all OWDSs and ACL to City of Malibu
Aug 12, 1999	Regional Board Resolution 99-13	El Rio septic staff report: Poorly maintained septic linked to nitrogen contamination in groundwater

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January 22, 1999	Haile, et al, 1999 epidemiology study	In Epidemiology July 1999, vol. 10, n. 4 22,085 subjects in epidemiology study at Surfrider, Will Rogers and Santa Monica showing increased risk to immersed-head swimmers for illness where fecal indicator bacteria are present.
1999	Dames and Moore study	Salt tracer, no pathogens found in wells within 200 feet, but tidal reversal confounds results
1999	URS Greiner study	Salt Tracer found at 20 feet in wells, but indicator bacteria not seen in short period test.
Dec. 12, 2002	Regional Board Resolution	Santa Monica Bay Bacteria Total Maximum Daily Load: beach pathogens attributed to loads from septic systems
March 21, 2003	EPA Malibu Creek Nutrient TMDL	Total Maximum Daily Load sets loads and numeric targets for total Nitrogen
2003	Questa study	Groundwater discharge to receiving water, quantified including volume from septic system discharge.
Aug 30, 2004	Stone study	Bacteria may enter receiving water where septic systems are found within 6-month travel time
Jan. 24, 2004	Regional Board Resolution	Malibu Creek and Lagoon bacteria TMDL: Tetra Tech surface water model sets loads for bacteria from septic systems
March 2006	Richard Viergutz, M.S. Thesis	Discharge of sewage-polluted groundwater into Malibu Creek and Lagoon resulting from groundwater surface interactions

Enterococcus as a Study Focus

Enterococcus is a bacteria indicative of the possible presence of etiological agents of human illness and a study focus for this analysis. Enterococcus was emphasized over fecal, total or Escherichia coli bacteria for the following reasons: (1) it is part of the flora of the human gut; (2) it is prevalent in discharge from septic systems into the leachfields in the Malibu Civic Center; (3) Annette Pruss' 1998 survey of epidemiology studies linking beach pathogens to human illness identified enterococcus as one of two bacteria correlating most strongly with highly credible gastrointestinal illness among swimmers; (4) The 58 sites sampled during the summers in Santa Monica Bay include data from the wet year of 2005 and the dry year of 2007; (5) it was correlated with increased human illness at Surfrider Beach, adjacent to the Civic Center, in the 1999 epidemiology study by Robert Haile and others; (6) the protocol for the sampling, transportation, and analysis of the most probable number of enterococcus colonies in 100 milli-Liters of water is well established in the refereed literature; and (7), the 1983 EPA marine recreational standard and its interpretation in the 2005 California Ocean Plan relate enterococcus density to both an acceptable illness threshold of 19 per 1000 swimmers and both a single sample and a geometric mean sample water quality objective.

Alternative indicators of human pathogens have been proposed, but the supporting research for candidates such as bacteroides or genetically defined species of enterococcus is insufficiently developed to support a new EPA criteria. In fact the 2005 study by Southern California Coastal Water Research Project or SCCWRP found bacteriodes in Ballona Creek, but not in Malibu Creek and Lagoon. Additional work is

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underway to determine if the density of bacteriodes retained after transport is sufficient for the species to serve as an indicator of human risk.

Species of enterococcus have also been identified in the feces of domestic animals, wild animals, birds, and in some plants. The genetic typing of enterococcus species in water along with the identification of other human-characteristic chemicals such as optical brighteners has been used to distinguish human from non-human enterococcus with some success in areas outside Malibu. The 1999 Haile epidemiology study results do not support dilution of enterococcus bacteria so as to preclude its value as an indicator of human illness. Specifically, the study found that for the same enterococcus densities, Surfrider Beach had a highly credible gastrointestinal illness with fever rate of 39 per 1,000 swimmers, which is higher than the 19 per 1,000 illnesses rate reported by EPA. The enterococcus concentration on the Malibu Civic Center beaches can be considered a conservative measure of the contribution of human fecal matter.

OWDS and Transport of Pathogens

Many studies have been completed within the last twenty years to characterize the transportation mechanisms of pathogens through the groundwater from the leachfield of septic systems or other OWDSs: Schaub and Sorber (1977) reported that viruses move by rapid infiltration and concluded that removal can be limited by low absorption rate of virus particles to soil. The authors used a mixed compound consisting of the tracer virus f2 and indicator bacteria in the tested septic tank and monitored the mitigation of indicators in well samples. It was found that enteric bacteria were quickly filtered by soil and concentrated on the soil surface; but the tracer viruses was not observed on the upper soil layers but was found in the down-gradient groundwater layers. Vaughn et al. (1983) also observed a preferential entrainment of bacteria, as opposed to viruses from septic discharge, in a shallow, sandy soil aquifer. These results illustrate that even when indicator bacteria are not present, viruses may still be present.

Goyal et al. (1979) further investigated the adsorption rates for different types or strains of viruses/bacteria to various types of soils. No specific viruses or bacteria were found to represent the general adsorptive behaviors of all viruses to soils, and no specific soil type can serve as a general model for all the soil types. Similarly, Chu et al. (2003) investigated the transportation rates of viruses passing through saturated and unsaturated soil columns. Strong correlations were found between virus adsorption and various factors, i.e. existence of metal oxides, water content, organic matter, pH, etc.

Bloch et al. (1990) presented a case study of a human virus infection (hepatitis A virus, HAV) due to groundwater contamination from on-site discharge system. The leachfield of the septic system in the studied site (a trailer park) was approximately 30 to 60 meters away from the drinking water well, and the author confirmed the direct association between septic discharge and virus infection. Fecal coliform was not significantly higher during the outbreaks period of hepatitis A.

These studies indicate the significant differences between viral and bacterial contaminants: viruses have the potential to penetrate the soil layers to a greater extent than bacteria. This highlights a limitation of using bacterial water quality indicators to predict viral groundwater contamination. However, it can be also implied that when higher densities of indicator bacteria occur, there is a higher risk that the soil layer can be contaminated by viruses. For example, Cuyk et al. (2004) reported a high correlation between virus concentrations and bacteria indicators in well-operated soil columns and field septic systems.

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Recent work also shows that the beach is a more complex hydrologic environment than the steady state condition previously modeled (Stone 2005 Malibu Risk Assessment). Episodic freshwater transport has recently been documented (Izbicki, 2009 in process). Bacteria densities have been tentatively linked to tidal and seasonal changes (Boehm et al., 2004; De Sieyes et al. , 2008, Izbicki, 2009 in press). Other researchers used sand column studies to show bacteria and virus retention and remobilization was related to the movement of organic material and bacteria and viruses have recently been shown to adhere and remain viable in beach material until remobilized (Yamahara et al., 2007; Azadpour-Keeley et al., 2003; Noble et al., 1996; Schaub et al., 1997, Schijven et al., 2002; Stramer et al., 1984).

In 2007, Nathalie Tifenkni provided a survey of particulate transport in the groundwater and noted that the existing models are deficient in successfully predicting the movement of organic particles. The survey specifically notes that work predicting the subsurface slowing of bacteria movement has not been paralleled by equally vigorous exploration of the subsurface enhancement of bacteria movement.

> ”A substantial research effort has been aimed at elucidating the role of various physical, chemical and biological factors on microbial transport and removal in natural subsurface environments. The major motivation of such studies is an enhanced mechanistic understanding of the these processes for development of improved mathematical models of microbial transport and fate. In this review, traditional modeling approaches are systematically evaluated. A number of these methods have inherent weaknesses or inconsistencies (page 1455)….For instance, calculations based on Tufenkji and Elimelech (TE) equation indicate that particles in the size range of [about] 2µm (e.g. many bacteria) are nearly twice as mobile in porous media than previously believed (page 1461)….The release (detachment) of microorganisms from sediment grain surfaces can be of considerable importance in natural subsurface environments and engineered water treatment systems…an improved understanding of.. factors controlling microbial release are required before practical incorporation of this process into mathematic transport models (page 1646)… Future areas for fundamental research in this area have been identified and include (i) inactivation kinetics of microorganisms in soils, (ii) role of protozoan grazing in removal of bacteria, (iii) mechanisms of microbial detachment from sediment grain surfaces,)iv) interactions between cell/cyst surface biomolecules and mineral surfaces, and (v) the influence of physical and geochemical aquifer heterogeneity on microbial transport (page 1468).”

Other possible mechanisms that may result in the preservation of enterococcus include elevated nitrogen and/or oxygen levels (Azadpour-Keeley et al., 2003; Yates, 1985, 1986) in the subsurface or on the beach face. In addition, septic plumes are now known to stay intact during subsurface movement (Groundwater Monitoring and Assessment Program: Baxter, Minnesota, 1999) limiting the impact of subsurface dilution of discharged enterococcus densities.

Studies relating OWDS to Beach Pathogens[6]

Research completed over the last ten years has expanded the understanding of beach bacteria sources . For example, it has been demonstrated that the fecal-indicator-bacteria enterococcus are present at many California beaches. In 2003(b), Borchardt et al. reported that the density of septic systems correlated with increased rates of infectious diarrhea in children in central Wisconsin. The authors found that viral diarrhea increased by 8% for every additional holding tank in 640 acres and bacterial diarrhea increase by 22% for every additional holding tank in 40 acres. While household wells were sampled for bacterial, risks were attributed to surface contact with pathogens near septic systems.

In 2004, Boehm et al. reported that groundwater discharge of microbial pollution moved from a shallow beach aquifer on to the beach face at Huntington Beach. While fecal indicator bacteria were found in only one groundwater sample, column studies show that the transport of enterococcus is not inhibited by sand collected in the field. In addition, radium isotopes characteristic of groundwater linked 38% of the enterococcus variation to groundwater discharge.

In 2007, Yamahara et al. reported in Environmental Science and Technology, Vol. 41, No. 12, that 91% of sampled California coastal beaches had enterococcus present in sand. The presence of a putative pollution source such as a river, wave shelter and surrounding anthropogenic land use correlated with higher enterococcus concentrations in the sands.

In 2008, De Sieyes et al. reported that fresh nutrient-rich groundwater discharges in fortnightly pulses into the ocean across a beach from adjacent septic systems and leachfields. While fecal indicator bacteria and human enterococcus genes were found in monitoring wells and attributed to pollution from adjacent septic systems, the concentrations of these pathogens did not increase with nutrients in the surf zone.

In 2009, the American Association for the Advancement of Science summarized studies identifying Methicillin Resistant Staphylococcus Aureus Bacteria (MSRA) in ocean water and on beaches in Florida.. Citizens have claimed an MSRA infection was contracted at Malibu beaches. The infections, which are resistant to antibiotics and are more commonly found in hospitals, are now known to be transmitted to beach water through contact with infected individuals and, according to one report, through municipal effluent. The ability of the bacteria to travel via sewage has not been quantified.

Enterococcus has been grown in the laboratory setting in unseeded beach sand (Yamahara et al., 2009) and found in a freshwater environment free from human impact (Tiefenthaler et al., 2008 Enterococcus has also been shown to persist in the beach sand and occur in higher concentrations in organic beach

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[6] Early Technical Reviewers recommended enhancements of staff's summary of studies on beach pathogens completed since 2004. While it is beyond the scope of this document to present a complete literature study on the topic, the summary emphasizes the scope of ongoing technical investigations in the field. The authors of the papers cited, some of whom were Early Technical Reviewers, wished staff to emphasize that additional study is necessary to characterize the physical, chemical and biological processes which allow bacteria and viruses to move through the groundwater for surface discharge. The authors should be contacted for the most up-to-date information on their research and the interpretation of the work already completed.

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debris where it may later be transported to near shore waters (Pednekar et.al, 2007; Yamahara et al., 2007).

These studies and others show that the beach is a more complex microbiological environment than was previously understood.

Potential Scenarios for Sources and Transport Mechanisms for Bacteria in the Malibu Civic Center.

Figure 10 shows the Malibu Civic Center with planned development (Questa, 2003), and the line of the cross section shown in Figure 11. The cross section shows possible paths of transport for the bacteria discharged into OWDS leachfields/seepage pits to Malibu Creek, Malibu Lagoon and the ocean. Note in the cross section that bacteria leaving OWDS in Malibu Colony or adjacent to Legacy Park have the shortest travel times and fewest opportunities for subsurface physical detention, chemical attack or biological predation.

The movement of septic system bacteria from the Civic Center area north of Pacific Coast Highway via subsurface transport to Surfrider Beach under summer conditions would require movement through the beach barrier into marine water (see Figure 11 [cross section]). Enterococcus from septics must survive physical, chemical and biological destruction in the subsurface before ocean discharge. Enterococcus from higher elevations within the watershed must travel further on the surface and both light and distance are known to cause de-activation of both viruses and bacteria (Azadpour-Keeley, 2003;Yates, 1985, 1986).

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Figure 10. Planned development in the Malibu Civic Center from Questa 2003 and cross section line

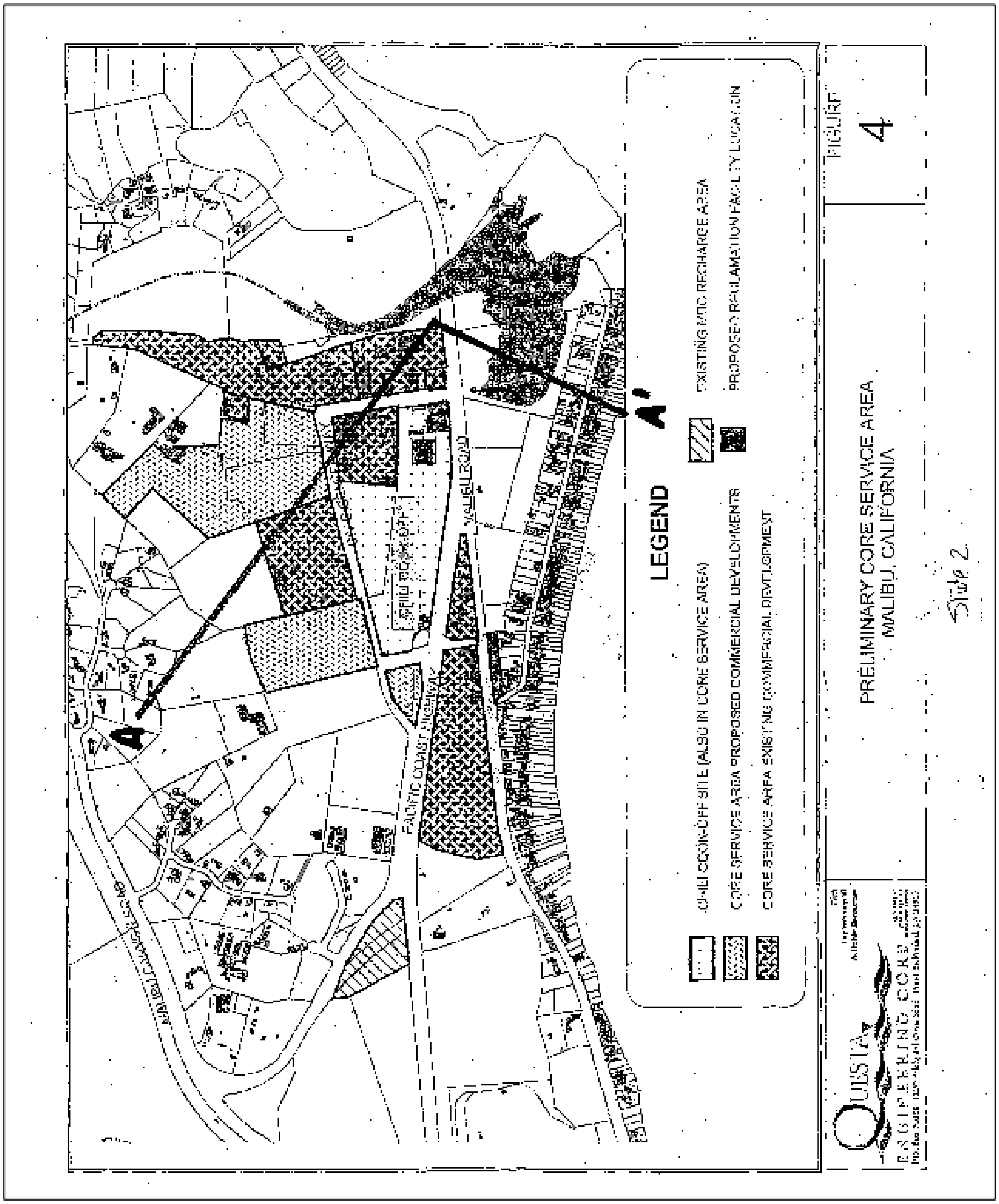
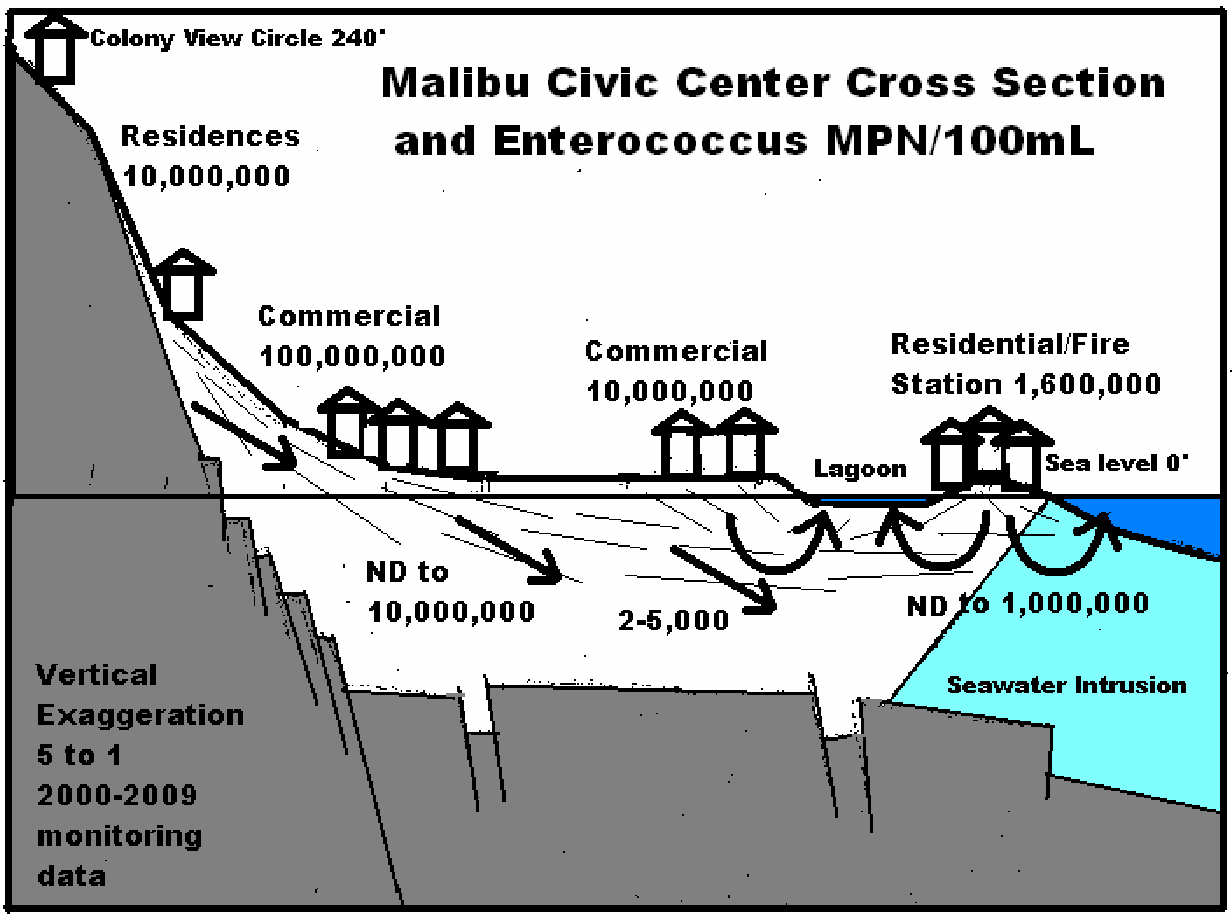


Figure 11. Cross Section A to A' showing facility and groundwater bacteria and flow paths



6. Conclusion

Malibu Creek, Lagoon, and nearby beaches are popular within the local community and as a destination for well over 1 million visitors per year. In the Basin Plan, the Regional Board has designated these waters for both water contact recreation (e.g. swimming) and non-contact water recreation (e.g. sunbathing, aesthetic enjoyment), and set standards, using the best available science, at levels that will protect human health.

As determined by the Regional Board and US Environmental Protection Agency, surface waters in the Malibu Creek Civic Center area are impaired for water contact recreation, and consistently have failed to meet State health and water quality standards set to protect swimmers and surfers in contact with the water. Repeated failures to meet standards set to protect public health have resulted in a poor water quality reputation for Surfrider Beach.

To examine the hydraulic connection of discharges from Onsite Wastewater Disposal Systems (OWDSs) through groundwater to nearby surface waters, staff evaluated more than 8,000 samples of wastewater effluent, underlying or nearby groundwater, and surface waters. Staff determined that pathogens from wastewaters are likely migrate to surface waters and that, consistent with data supporting the designations of impairments, threaten human health. This conclusion is based on our analysis of the indicator bacteria enterococcus. The levels of this bacteria do not meet standards protective of human health. Staff also determined that risks of infectious disease from water contact recreation were elevated at beaches in the Malibu Civic Center based on work by Haile et. al. 1999.

Staff also reviewed numerous previous studies, and found conclusions from these other studies to be consistent with staff's determination of impairment to the beneficial use of water contact recreation.

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ATTACHMENT 3-A: Monitored Santa Monica Bay Beaches[7]

No	CSMP	Location	Linked Watershed	Treat-ment Type	Strom drain/ Freshwater	Total Acres
1	SMB 1-01	Arroyo Sequit Creek, Leo Carrillo State Beach	Arroyo Sequit	Septic	Y	7,549
2	SMB 1-02	El Pescador State Beach	Los Alisos	Septic	N	2,396
3	SMB 1-03	El Matador State Beach	Encinal	Septic	N	1,794
4	SMB 1-04	Trancas Creek	Trancas	Septic	Y	6,514
5	SMB 1-05	Zuma Break at Zuma Beach	Zuma	Septic	Y	6,339
6	SMB 1-06	Walnut Creek	Ramirez	Septic	Y	3,334
7	SMB 1-07	Ramirez Canyon at Paradise Cove Pier	Ramirez	Septic	Y	3,334
8	SMB 1-08	Escondido Creek	Escondido	Septic	Y	2,295
9	SMB 1-09	Latigo Canyon	Latigo	Septic	Y	813
10	SMB 1-10	Solstice Creek at Dan Blocker County Beach	Solstice	Septic	Y	2,841
11	SMB 1-11		Corral	Septic	Y	4,280
12	SMB 1-12	Marie Canyon Strom Drain on Puerco Beach	Corral	Septic	Y	4,280
13	SMB 1-13[8]	Sweetwater Canyon on Carbon Beach	Carbon	Septic	Y	2,320
14	SMB 1-14	Las Flores Creek on Las Flores State Beach	Las Flores	Septic	Y	2,897

[7] Data as reported in Santa Monica Bay beaches Bacteria TMDLs and SMB beaches Bacteria TMDL Coordinated Shoreline Monitoring Plan

15	SMB 1-15	Big Rock Beach	Piedra Gorda	Septic	Y	664
16	SMB 1-16	Pena Creek on Las Tunas County Beach	Pena	Septic	Y	608
17	SMB 1-17	Tuna Canyon	Tuna	Septic	N	1,013
18	SMB 1-18	Topanga Canyon on Topanga State Beach	Topanga	Septic	Y	12,575
19	SMB 2-01	Castlerock storm drain aka Parker Mesa Storm Drain	Castlerock	Sewer	Y	4,976
20	SMB 2-02	Santa Ynez Storm Drain	Santa Ynez	Sewer	Y	1,203
21	SMB 2-03	Will Rodgers State Beach 1/4 mile east of Gladstones	Santa Ynez	Sewer	N	1,203
23	SMB 2-04	Pulga Storm Drain on Will Rodgers State Beach	Santa Ynez	Sewer	N	1,203
24	SMB 2-05	Bay Club Storm Drain on Will Rodgers State Beach	Santa Ynez	Sewer	N	1,203
25	SMB 2-07	Santa Monica Canyon	Santa Monica Canyon	Sewer	Y	10,088
26	SMB 2-08	Venice Beach Pier	Venice Beach	Sewer	N	5,241
27	SMB 2-09	Topsail Street, Venice Beach	Venice Beach	Sewer	N	5,241
28	SMB 2-10	Culver Storm Drain	Dockweiler	Sewer	Y	6,573
29	SMB 2-11	North Westchester Storm Drain	Dockweiler	Sewer	Y	6,573
30	SMB 2-12	Dockweiler Beach	Dockweiler	Sewer	N	6,573
31	SMB 2-13	Imperial Highway Storm Drain	Dockweiler	Sewer	Y	6,573
32	SMB 2-14	Hyperion Plant, Dockweiler Beach	Dockweiler	Sewer	N	6,573
33	SMB 2-15	Grand Ave, Dockweiler Beach	Dockweiler	Sewer	Y	6,573
34	SMB 3-01	Montana Ave, Santa Monica Storm Drain, Santa Monica State Beach	Santa Monica	Sewer	Y	8,850

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35	SMB 3-02	Wilshire Storm Drain, Santa Monica State Beach	Santa Monica	Sewer	Y	8,850
36	SMB 3-03	Santa Monica Pier Storm Drain, Santa Monica State Beach	Santa Monica	Sewer	Y	8,850
37	SMB 3-04	Pico-Kenter Storm Drain	Santa Monica	Sewer	Y	8,850
38	SMB 3-05	Ashland Storm Drain	Santa Monica	Sewer	Y	8,850
39	SMB 3-06	Rose Ave Storm Drain, Venice Beach	Santa Monica	Sewer	Y	8,850
40	SMB 3-07	Brooks Ave Storm Drain, Venice Beach	Santa Monica	Sewer	Y	8,850
41	SMB 3-08	Venice Pavillion	Santa Monica	Sewer	Y	8,850
42	SMB 3-09	Strand Street, Santa Monica State Beach	Santa Monica	Sewer	N	8,850
43	SMB 4-01	San Nicholas Canyon	Nicholas	Septic	Y	1,235
44	SMB 5-01	40th Street, Manhattan Beach	Hermosa	Sewer	N	2,624
45	SMB 5-02	28th Street Drain, Manhattan Beach	Hermosa	Sewer	Y	2,624
46	SMB 5-03	Manhattan Beach Pier	Hermosa	Sewer	Y	2,624
47	SMB 5-04	26th Street, Hermosa Beach	Hermosa	Sewer	N	2,624
48	SMB 5-05	Hermosa Beach Pier	Hermosa	Sewer	N	2,624
49	SMB 6-01	Herondo Storm Drain	Redondo	Sewer	Y	3,544
50	SMB 6-02	Redondo Beach Pier	Redondo	Sewer	Y	3,544
51	SMB 6-03	Sapphire Street	Redondo	Sewer	N	3,544
52	SMB 6-04	Topaz Groin	Redondo	Sewer	N	3,544
53	SMB 6-05	Avenue I	Redondo	Sewer	Y	3,544
54	SMB 6-06	Malaga Cove	Redondo	Sewer	N	3,544
55	SMB BC-01	Ballona Creek	Ballona Creek	Sewer	Y	81,980

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56	SMB MC-01	Malibu Point on Malibu State beach	Malibu Creek	Septic	Y	70,410
57	SMB MC-02	Breach Point of Malibu Lagoon on Malibu State Beach	Malibu Creek	Septic	Y	70,410
58	SMB MC-03	Malibu Pier on Carbon Beach near Malibu Creek	Malibu Creek	Septic	Y	70,410
59	SMB 7-01	300 Paseo Del Mar, Palos Verdes Estates	Palos Verdes Peninsula	Sewer		10,023
60	SMB 7-02	Bluff Cove, Palos Verdes Estates	Palos Verdes Peninsula	Sewer		10,023
61	SMB 7-03	Long Point, 7200 Palos Verdes Drive South, Rancho Palos Verdes	Palos Verdes Peninsula	Sewer		10,023
62	SMB 7-04	6000 Palos Verdes Drive South, Rancho Palos Verdes	Palos Verdes Peninsula	Sewer		10,023
63	SMB 7-05	Portuguese Bend Club, Rancho Palos Verdes	Palos Verdes Peninsula	Sewer		10,023
64	SMB 7-06	White's Point/Royal Palms County Beach, San Pedro	Palos Verdes Peninsula	Sewer		10,023
65	SMB 7-07	Midway between White Point County Beach and Wilder Annex	Palos Verdes Peninsula	Sewer		10,023
66	SMB 7-08	Point Fermin/Wilder Annex, San Pedro	Palos Verdes Peninsula	Sewer		10,023
67	SMB 7-09	Cabrillo Beach, San Pedro	Palos Verdes Peninsula	Sewer		10,023

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Appendix T3-C[9]										
Enterococcus Frequency distributions for Civic Center Beaches and Selected Correlation Coefficients										
Malibu Pier						**Surfrider Beach**				
MPN/100mL	2005	2006	2007	2008		MPN/100mL	2005	2006	2007	2008
<10	0.417	0.067	0.464	0.233		<10	0.21	0.262	0.58	0.435
10	0.25	0.433	0.286	0.367		10	0.11	0.123	0.221	0.183
25	0.167	0.033	0.071	0.067		25	0.14	0.131	0.015	0.099
50	0.167	0.2	0	0.133		50	0.19	0.154	0.076	0.076
100	0	0.2	0.107	0.1		100	0.2	0.138	0.076	0.115
250	0	0	0.071	0.067		250	0.06	0.123	0.015	0.053
500	0	0.033	0	0.033		500	0.01	0.031	0.015	0.015
1000	0	0	0	0		1000	0.07	0.031	0	0
2500	0	0.033	0	0.033		2500	0	0.008	0	0.023
5000	0	0	0	0		5000	0	0	0	0
>5000	0	0	0	0		>5000	0	0	0	0
sum of frequencies	1	1	1	1.033			1	1	1	1
Correlation Coefficients			**2005-2006**	**2006-2008**		**Correlation Coefficients**			**2005-2006**	**2006-2008**
2007-2008	**2006-2007**		0.437	0.847		**2007-2008**	**2006-2007**		0.904	0.871
0.8075	0.427					0.98	0.78			

[7] Shaded boxes indicate corrections of clerical errors since 9/09/2009 Draft

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